CHAPTER 1

GENERAL

1-1. Purpose.

This manual provides Department of the Army and Air Force policy and guidance for design criteria and standards for electrical power supply and distribution systems.

1-2. Scope.

The design criteria and standards contained within are the minimums acceptable for Department of the Army and Air Force installations for efficiency, economy, durability, maintainability, and reliability of electrical power supply and distribution systems. Where special conditions and problems are not covered in this manual, applicable industry standards will be followed. Modifications or additions to existing systems solely for the purpose of meeting criteria in this manual will not be authorized. The criteria and standards herein are not intended to be retroactively mandatory. The word “will” identifies guidance. The word “shall” identifies policy and is used when writing legal, contractual, requirements such as statements of work, specifications or any other documents that require compliance from the commercial/industrial sector. Clarifications of baseline design criteria, standards, policy, and guidance should be obtained through normal Army and Air Force channels, from HQUSACE CEMP-ET, Washington, DC 20314-1000 or SQ AFCESA/ENE, 139 Barnes Drive, Suite 1, Tyndal AFB, FL 32403-5319.

1-3. References.

Appendix A contains a list of references used in this manual.

1-4. Standards and Codes.

Applicable electrical industry codes, standards, or publications referenced will apply to equipment, materials, and construction covered herein. The minimum requirements of the latest version of NFPA-70, the National Electrical Code (NEC), and ANSI C2, the National Electrical Safety Code (NESC), will be met and exceeded when more stringent requirements are specified and/or dictated.

1-5. Power Supply Design Criteria.

The designer will review the project requirements documents (Project Development Brochure, DD Form 1391 (FY, Military Construction Project Data), project requirements outline, source data, functional flow diagrams, space requirements, security requirements, etc.) to determine the power supply configurations required to achieve the necessary degree of reliability, durability, maintainability, efficiency, and economy.

a. Reliability. System reliability describes and quantifies the ability of a system to consistently provide power to a facility. The designer will request using agency to provide the allowable frequency and duration of both forced and maintenance outages. The designer will evaluate the supply source reliability data (outage records) and determine the system configuration required to meet the required availability. For supply scenarios where the allowable outage frequency and duration requirements cannot be met with a single-source design, the designer will develop mathematical and supporting cost models for multiple-source or redundant-feed distribution systems to achieve the required availability, utilizing IEEE Std 493 methods. An alternative comparison assessment will be developed to evaluate the reliability choices utilizing IEEE Std 493 methods.

b. Durability. Electrical systems and electrical equipment will be designed for the design life of the facility: 25 years for permanent construction, 6 to 24 years for semi-permanent construction, and 5 years for temporary construction.

c. Maintainability. The design of electrical systems will incorporate features which provide access space for maintenance in accordance with the NEC and NESC, and means to replace equipment and field installed wiring without significant demolition and reconstruction of parts of the facility.

d. Economy. Agency criteria and AR 11-18 establish the economic consideration requirements which will be assessed for each facility. For Air Force, refer to AFR 173-15.

1-6. Electrical Power Systems.

Electrical power systems for Army and Air Force installations can be composed of subtransmission lines to main substations; distribution lines to distribution substations; utilization lines to distribution transformers; and generators to provide emergency, stand-by, and/or prime power for mission essential/critical loads. Generally, for Army base-wide distribution changeouts, the preferred CONUS voltage is 13.2 kV or 13.8 kV three-phase, three-wire, with delta primary and wye secondary transformer connections. When extending existing distribution systems, the preferred distribution voltage is the same as the existing distribution voltage. Use of 15 kV nominal-class systems is preferable to 5 kV nominal-class systems unless system studies indicate a clear advantage over the 15 kV system. Use of solidly grounded, multiple-grounded systems is preferred over single-grounded or ungrounded systems. For Air Force, the preferred CONUS distribution is 12,470Y/7,200 volt, three-phase, with delta primary and wye secondary transformer connections. Voltages for facilities outside of the United States are specified in AFM 86-3.

1-7. Design Procedures.

Electrical power supply and distribution features will be planned/delineated concurrently with planning stages of new installations and/or new facilities on existing installations. The design process starts with the DD Form 1391, Military Construction Project Data. This form provides information necessary to categorize the power requirements of the project. Two vital pieces of information are contained in the form: the scope of the project which includes restoration, new facility, or new installation (these all require different approaches); and the mission classification which includes mission essential, or mission support. (Each is authorized a different degree of importance in the hierarchy of power supply contigurations and equipment.) The next part of the design process involves estimating the power load requirements; defining the measures to be employed to meet the criticality requirements; and defining the project power source requirements. At this point a majority of the design bases can be formulated from the previous assessments and results, and final design features and configurations can be developed.

a. New installations. Electrical power supply and distribution systems for new installations will conform to prevailing utility company practices for that geographical area insofar as they do not conflict with criteria, standards, and policy contained within this manual.

b. Existing installations. Design for electrical power supply and distribution systems for new facilities on existing installations will be coordinated with the Facility Engineer or the Base Civil Engineer to assure compatibility with the electric utility master plan. Designs will be compatible with existing construction insofar as it does not conflict with criteria, standards, codes, and policy contained within this manual.

c. System configurations. Only radial, loop, or selective configurations as illustrated in figure l-l will be used. The configuration proposed will be commensurate with the degree of reliability required by the mission or use of the facility. The additional cost required to install loop or selective systems will be justified. Individual components such as loop or selective switches at transformers will be considered where the project will need increased reliability in the future. Special cases, involving large demands or high reliability requirements, may make the installation redundant sources of supply advisable. Hospital primary circuit arrangements will be in accordance with the requirements of MIL-HDBK 1191, Medical and Dental Treatment Facility Criteria, and other Medical Facilities Design office criteria.

d. Short-circuit and coordination studies. Short-circuit and protective devices coordination studies will be in accordance with IEEE Std 242 and TM 5-811-14. Both linear and nonlinear loading will be considered. Selection of protective devices and switchgear for a new electrical system will be based on a short-circuit protective device coordination analysis. For additions or modifications to an existing distribution system, the analysis will include all of the protective devices affected in the existing system. All protective devices will be properly coordinated to provide selective tripping.

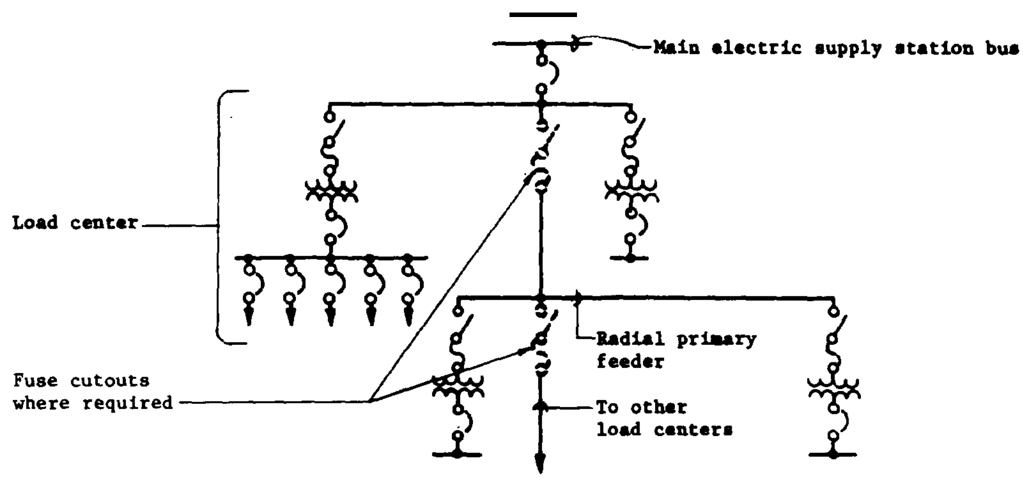
e. Expansion. Electrical power supply and distribution systems will be designed so that expansion will be possible. Refer to IEEE Std 141 for additional and more detailed information regarding the expansion of electrical systems.

1-8. Evaluation and Selection of Energy Systems.

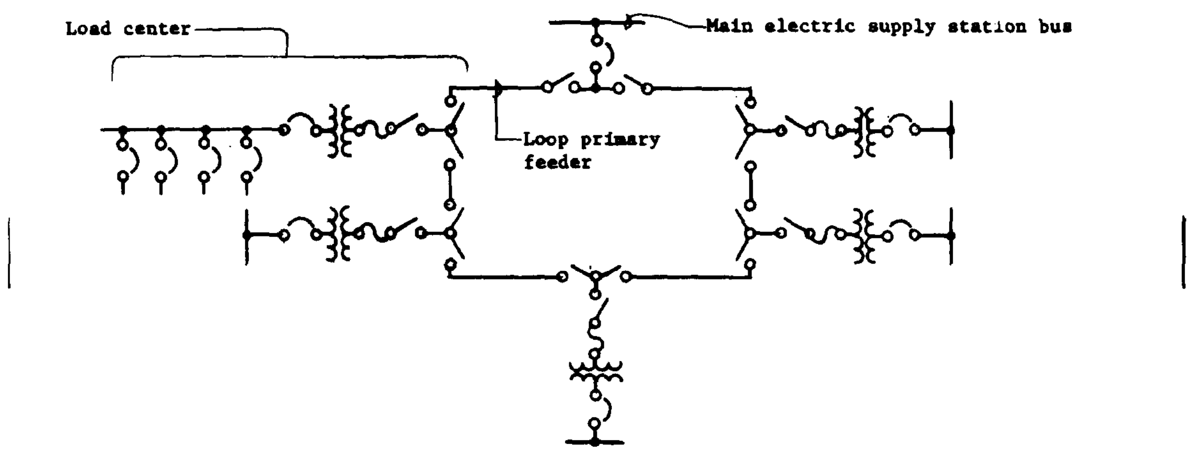
a. Selection of electrical energy sources for new installations. The most economical electrical energy source will be selected based on criteria and guidelines contained in agency criteria.

(1) *Feasibility study.* Where necessary to determine the most economical supply system, a life-cycle-cost analysis will be performed in accordance with methods discussed in 10 CFR 436, FEDERAL ENERGY MANAGEMENT AND PLANNING PROGRAMS. Choices include supply from a private, government owned generator plant, co-generation, solar energy, or combination of options.

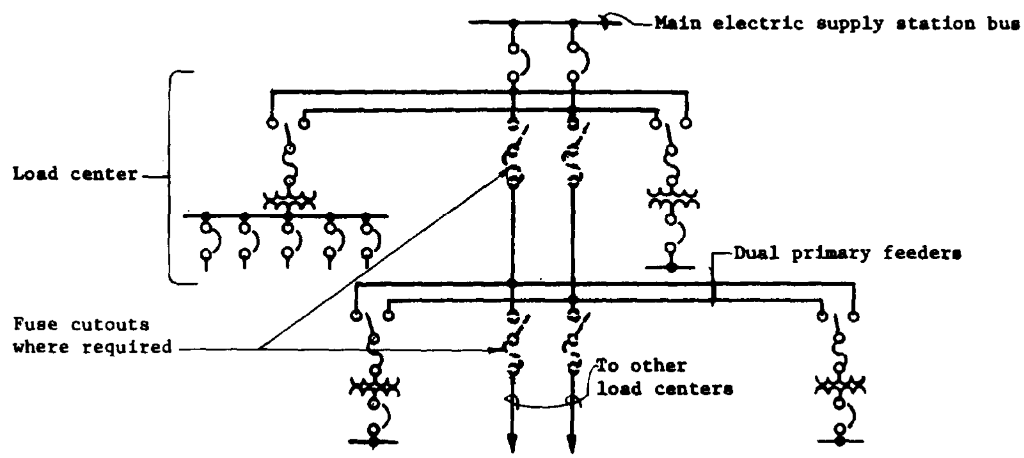
(2) *Potential energy sources.* In preparing feasibility studies, the potential energy sources compared will include coal, oil, and purchased electricity. Where applicable, refuse-derived, geothermal, or biomass-derived fuel will be considered. Factors affecting the choice of energy source will include availability, reliability, land right-of-way requirements, station or plant site needs, first costs for



POOREST AVAILABILITY - RADIAL SYSTEM



INTERMEDIATE AVAILABILITY - LOOP SYSTEM



GREATEST AVAILABILITY - SELECTIVE SYSTEM

US Army Corps of Engineers

Figure 1-1. Primary Distribution Arrangements Commonly Used.

the installation including any pollution abatement requirements, and annual costs for energy and operating personnel wages.

b. Selection of electrical energy sources for existing installations. Selection of an electrical energy source will be made when the existing source is inadequate to supply the requirements for the facility being added. If the facility is incorporated as a part of the overall installation master planning program, then the energy needs should have been forecast in the electrical systems master planning, and determination already made as to whether the existing electrical energy source should be expanded or whether some other alternative would be more economical. When the master plan does not provide the contemplated electrical requirements, an engineering study will be prepared.

(1) *Engineering studies.* Outside energy supplies will be evaluated based on the following:

(a) Reliability of the source.

(b) Cost of energy to the installation, based on projected demand and usage requirements.

(c) The suppliers ability to serve the present and the expected load for the next 5 years.

(d) System outages over the last five years, if available. Where outage information for at least one year is not available, or where it is meaningless because it applies to a system since changed, the system being considered will be evaluated on the basis of the utilities reliability projections.

(2) *Electrical master planning.* When an electrical master plan is not available, existing facilities will be evaluated by making a physical inspection of the existing facilities and accumulating the following data:

(a) Condition and characteristics of the existing off-site electrical energy sources including data previously listed.

(b) Number, condition, and characteristics of prime and auxiliary generating plants.

(c) Load information.

1-9. Design Analysis.

The designer preparing plans and specifications for work covered in this manual will also prepare an accompanying design analysis. The design analysis will completely cover the electrical design requirements for electrical systems necessary to the project. The design analysis will also be used to justify decisions recommended in concept or feasibility studies, although a separate section is not required if necessary material and computations are contained in a study, either in the body or in an appendix. The analysis will be submitted in two parts, a basis for design and design computations.

a. Basis for design. The basis for design will include a concise outline of functional features, including a description of existing systems and other considerations affecting the design. In addition, a full description of any special requirements and justification for any proposed departure from standard criteria are required.

(1) *Exterior electrical distribution systems.* The description of exterior electrical distribution systems will include statements on all features relevant to the specific project as follows:

(2) *Electrical power sources.* Electrical characteristics of the electrical power supply to an entire installation, or that portion of the installation involved, including circuit interrupting requirements and voltage regulation will be covered. A statement discussing the adequacy of the existing electrical power supply (including primary feeders) at the point of take-off will be given. If the electrical power source is inadequate, a statement of the measures proposed to correct the deficiency will be included. If a new electrical power source or local electrical generation is required, the various possibilities will be covered, except where the design directive has stipulated requirements. The advantages and disadvantages of various suitable methods will be analyzed and cost comparisons submitted. Where a design directive permits a choice among alternatives, the merits of each alternative will be examined. If the use of a certain system or equipment has been directed and the designer recommends another approach, the designer will indicate any deviation from the directed design and justify such deviations.

(3) *Loading.* An estimate of total connected loads, power factors, demand factors, diversity factors, load profiles where required, resulting demands, and sizes of proposed transformers to serve either the complete project or the various portions involved will be provided. Transformer peak loads and load cycling will be analyzed for transformers when appropriate. Designer will coordinate estimates with the using agency.

(4) *Electrical distribution systems.* The basis for selection of primary and secondary distribution voltages, and of overhead or underground construction will be provided. The proposed type of conductors such as copper or aluminum, bare or insulated, where each type is used, and any special basis for selection are required. Statements describing pertinent standards of design such as voltage drop, maximum primary circuit interrupting requirements, physical characteristics of overhead or underground circuits, switching, circuit protection, lightning protection, type of lighting units, and lighting intensities are required. Elec-

trical supply system sectionalizing for operation and maintenance will be defined, together with a description of switching and redundant circuits required to meet or optimize system availability. Any provisions for communication circuits to be installed by others, either aerially or underground, will be described.

(5) *Underground justification.* The basis for design will justify proposed underground construction by citing either criteria or authority for waiver of criteria.

(6) *Work performed by others.* If functional adequacy of the design is contingent on work to be performed by the Using Agency or the local utility, the basis for design will describe the limits of such work and the responsible agency.

b. Electrical generating plants. Wherever electric generating plants are required, pertinent data will be included in the basis for design.

(1) *Loading.* The estimated connected load, maximum demand, average demand, minimum demand, number of units proposed, their kW ratings, and reasons for the selection of these units will be indicated.

(2) *Prime mover specifications.* The class of plant, type of starting system, type and grade of fuel, and approximate storage capacity will be covered. The type of plant, whether completely manual, fully automatic, or semiautomatic, with reasons for the selection will be noted.

(3) *Voltage selection.* The selected voltage and reasons for the choice will be given. If commercial electrical power is not provided, the reasons why commercial power is not used will be stated. If operation in parallel with the serving utility is planned, a written utility company statement is necessary affirming agreement with this mode of operation.

(4) *Frequency and voltage regulation.* Frequency and voltage regulating requirements, including requirements for parallel operation, will be listed. A statement will be made that standard equipment is to be specified; where special equipment such as precise electrical power equipment is proposed, this special equipment will be fully justified. The additional cost of special equipment will be covered.

(5) *Cooling and heat recovery systems.* The type of cooling system and reason for selection is required, along with a description of the type of waste heat recovery, if any. An explanation is required to justify not utilizing waste heat.

c. Main electric supply stations. Where a main electric supply station is provided, the utility's system will be described including the utility's recommendations. Where pertinent, the utility's systems will also be described relative to adequacy and dependability, along with other applicable data covered in the requirement for engineering studies.

d. Design computations. Computations will be provided to indicate that materials and systems are adequate, but not over-designed, and are correctly coordinated. Computations will be provided for (but not limited to) conductor sizing, cable pulling, strength requirements (structures, poles, concrete pads, supports, etc.), pole line span lengths, generator and transformer capacities, switch and switchgear ratings, and protective device selection. Load flow and voltage drop calculations will be provided for new distribution systems, feeders where large loads are being added, and for line extensions where loads are being placed on lines far from the substation or other source. Short-circuit and protective device calculations will be provided for new substations, distribution feeders from existing substations, and where new facilities requiring protective devices are to be installed. The calculations should provide adequate conductor and equipment short-circuit withstand-ampacity and demonstrate coordination under the upstream devices. Protective device calculations are mandatory when relay and circuit breaker trip settings must be determined. Situations where system coordination is not achievable will be noted. Short circuit and protective device calculations will be in accordance with TM 5-811-14 and IEEE STD 242. Grounding system calculations will be performed in accordance with IEEE Std 242 and Std 80.

1-10. Service Conditions.

Temperature, humidity, and other climatological factors as well as altitude will require special design techniques at some installations. Design techniques will comply with the standards listed in table l-l.

a. Artic conditions. Basic engineering practices governing design and construction of electrical power systems in temperate areas will be applied to arctic and subarctic zones. Modifications, as necessary, in accordance with TM 5-349, TM 5-852-5, and AFM 88-19, will be made to combat snow and ice above ground and permafrost conditions in underlying subsoils. Methods used in temperate zones for installing electrical distribution poles are adequate in most cases; occasionally, special pole construction techniques, using cribs and tripods or blasting or drilling into the permafrost, will be required. Utilidors, which are usually rigid, insulated, and heated conduits with either crawl- or walk-through space for servicing and which are usually installed underground, may also be used.

Table 1-1. Service Conditions.

Item of Equipment	*Standard*
Batteries	IEEE 484
Seismic Design of Substations	IEEE 693
Battery Chargers	UL 1236
Instrument Transformers	IEEE C57.13
Switchgear	IEEE C37.20.1
	IEEE C37.20.2
	IEEE C37.20.3
Neutral Ground Resistors	IEEE 32
Power Circuit Breakers (Above 1000 Volts)	IEEE C37.04
Molded-Case Circuit Breakers	IEEE C37.13
Power Fuses	IEEE C37.40
Relays, Electrical Power Apparatus	IEEE C37.90
Step-Voltage Regulators	IEEE C57.15
Surge Arresters	IEEE C62.1
Switches	IEEE C37.30
Transformers	IEEE C57.12.00
Switchboards	NEMA PB 2

b. Tropic conditions. Basic engineering practices governing design and construction of electrical power systems in temperate areas will be applied to tropic zones. Potential problems which may result from corrosion and termite infestation, as well as the feasibility of using local materials, will be investigated in order to select the most suitable elements for the system. Outdoor switchgear will be enclosed and have space heaters with automatic controls. In typhoon areas, design will provide sufficient strength for the extreme wind loading conditions encountered. Where fungus control is required, the following paragraphs will be edited and included as a part of the project specifications as required:

(1) Contact surfaces of devices such as switches, fuses, and circuit breakers need not be treated. Other materials and components which are inherently fungus-resistant or are protected by hermetic sealing need not be treated.

(2) Circuit elements, not covered in above paragraph and which have a temperature rise of not more than 75 degrees F when operating at full load shall be treated in accordance with MIL-T-152. Circuit elements include, but are not limited to, cable, wire, terminals, switchgear, panelboards, capacitors, and coils.

(3) Circuit elements, such as motor coils, dry-type transformers, and similar electrical components, which have a temperature rise exceeding 75 degrees F when operating at full load shall not be coated with a fungitoxic compound. Instead, such components shall be given two coats of varnish and one sealer coat, both conforming to Type M, Class 130 of MIL-I-24092. Coats shall be applied by the vacuum-pressure, immersion, centrifugal, pulsating-pressure, or the built-in method so as to fill interstices in the coils and preclude the entrapment of air or moisture. The sealer coat may also be applied by brushing or spraying.

c. Corrosive or contaminated atmospheres. Upgrading of equipment located in atmospheres where corrosion occurs (because of excessive humidity or from industry contamination which may be intensified by fog) will be provided only where local practice indicates the additional cost is justified.

(1) *Upgrading corrosion resistance.* Where a better than standard coating is required, a salt spray test will be specified for the finish. Length of the testing period will be in accordance with standard practice for the area.

(2) *Insulating devices.* Where over insulation in contaminated areas is required, bushings will be specified for the next higher basic impulse level (BIL) than required for that device insulation class.

d. Insect and rodent damage. The applications listed below will be investigated and implemented, as required, in areas where insert and rodent damage to underground cable installations is a problem. Proven local practice will also be followed.

(1) Use armored cable.

(2) Use cable with higher voltage rating.

(3) Use cable with full concentric neutral.

(4) Install animal guards around existing concrete pads and around pipe entrances on wood walls.

(5) On new installations, install buried fiberglass pads that animals cannot penetrate.

(6) Specify cable with rodent protection armor.

(7) Specify seals or cover all crevices greater than ¼-inch.

(8) Select foundation area plantings which do not compliment local area pest habitats.

(9) Do not use toxic chemical treatment of the soil.

e. Seismic design. The seismic design of electrical installations will comply with agency criteria; TM 5-809-10; and AFM 88-3, Chapter 13. The seismic design of electric substations will comply with IEEE 693.

f. Electromagnetic pulse (EMP) and high-altitude electromagnetic pulse (HEMP). EMP and HEMP requirements will be in accordance with MIL STD 188-125 and MIL HDBK 423.

g. Environmental compliance. The design will provide electrical systems which comply with Federal, state, and local environmental regulations. Transformer dielectric information in chapter 8 will be applied to all dielectric-filled equipment.

1-11. Explanation of Abbreviations and Terms.

Abbreviations and terms used in this manual are explained in the glossary.